The Straw-Tube Tracker of the ZEUS Detector at HERA

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Outline:

- Motivation
- Design and Construction
- Operation and Performance
- Tracking results

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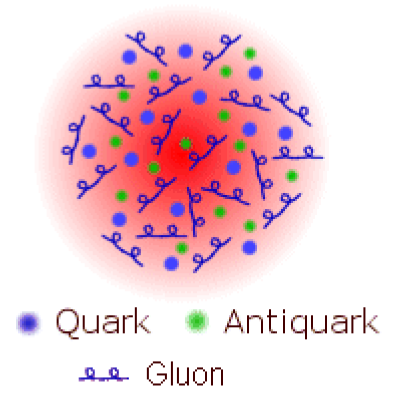
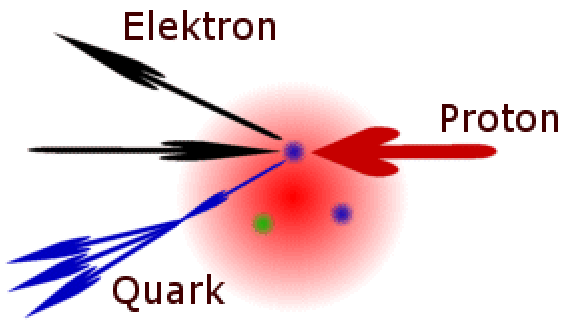
HERA-Physics & Motivation

Investigate proton structure

The Proton

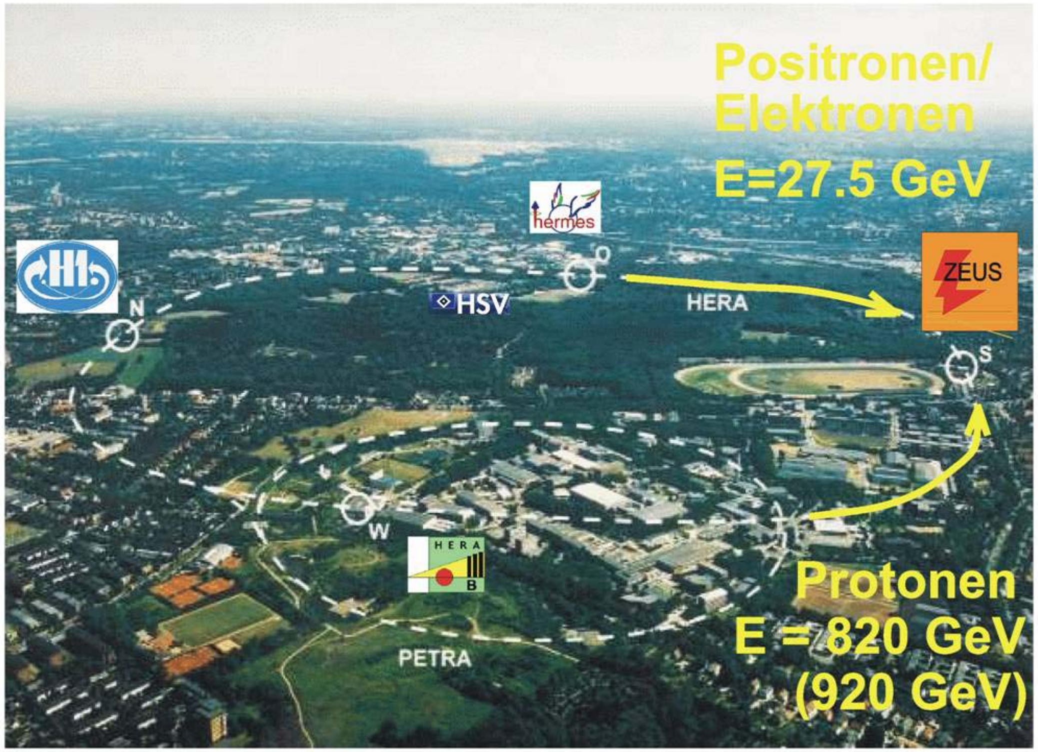


→ Use electron/positron as probe



A scattering process at HERA

The HERA accelerator



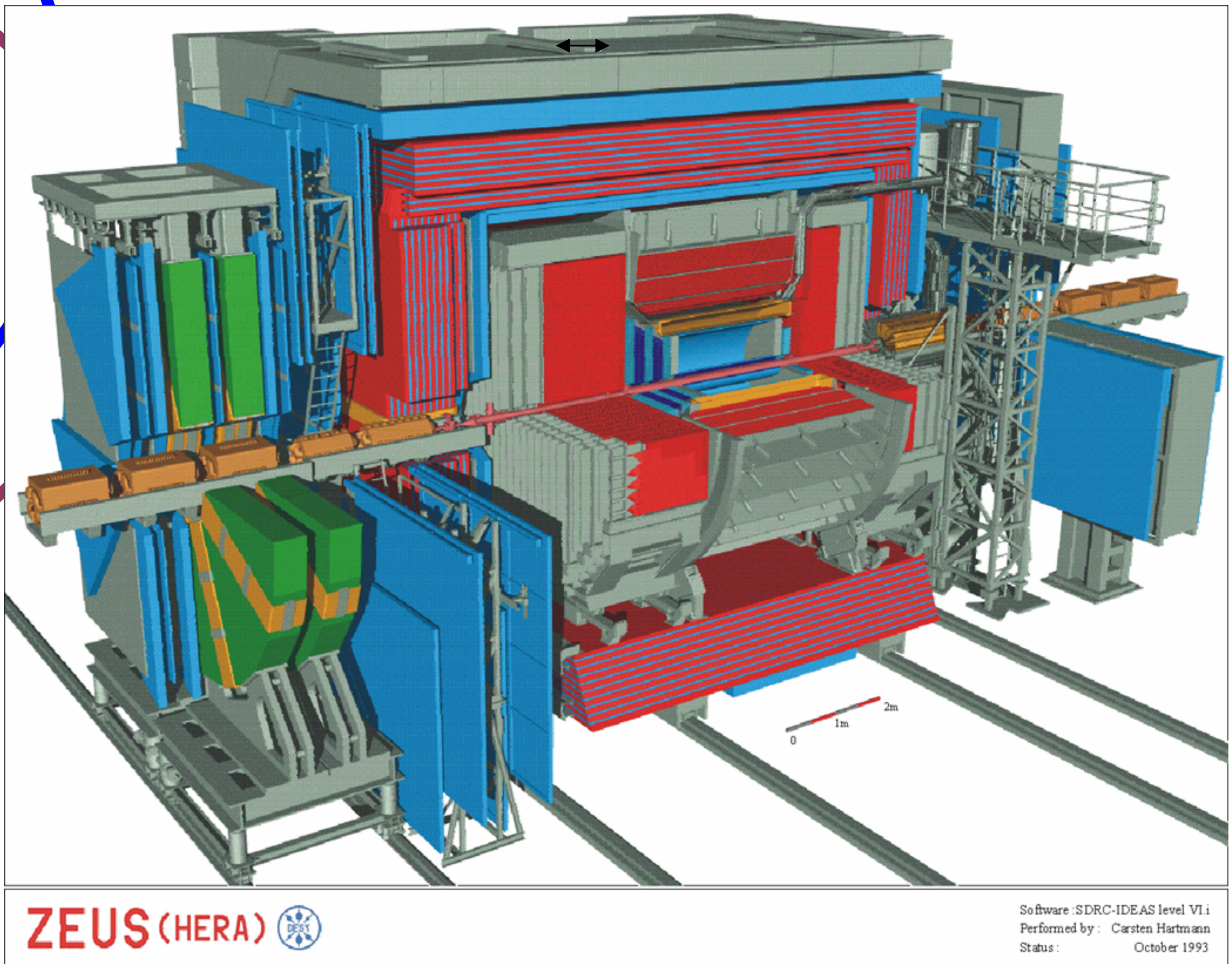
- Electron energy: 27.5 GeV
- Proton energy: 920 GeV
- CM-energy: 318 GeV

- typ. electron current: 60 mA
- typ. proton current: 100 mA

- Number of bunches: 210
- Bunchcrossing time: 96 ns

e $\longrightarrow$ $\longleftarrow$ p

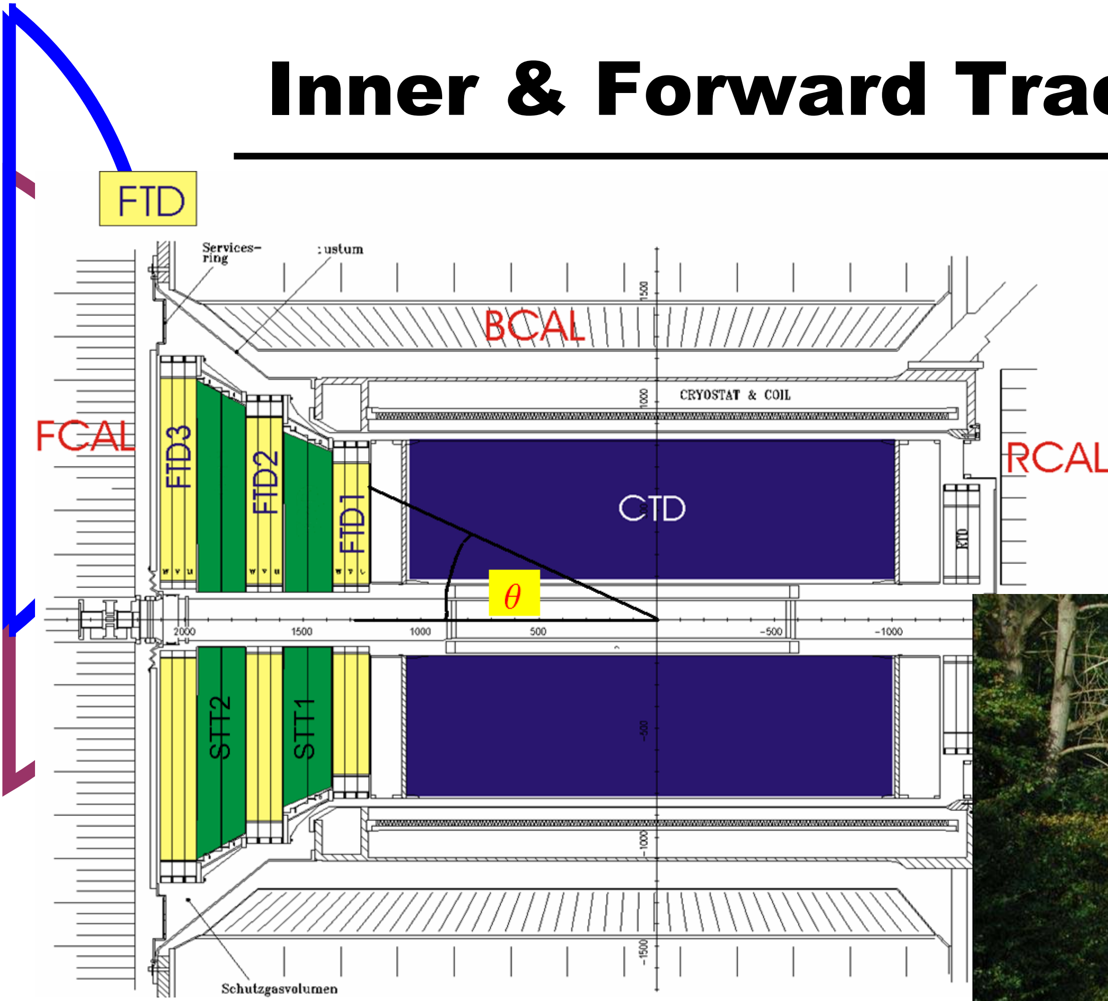
The ZEUS-Detector



Asymmetric beams:
e → ← p
↓
asymmetric detector

Special emphasis on the forward (proton) direction
↓
Forward Detector

Inner & Forward Tracking Detectors



Central tracking detector:

CTD for $\theta > 25^o$

Forward tracking detectors:

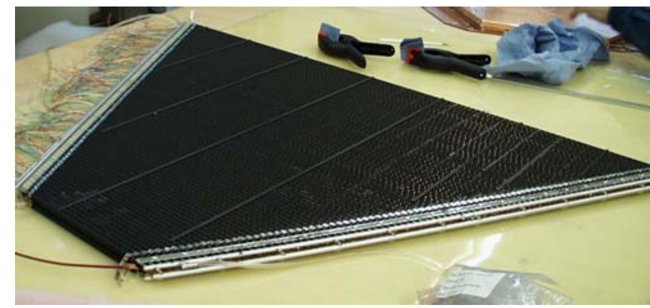
STT+FTD for $6^o < \theta < 25^o$

STT installed in 2001 shutdown

Straw-Tube Tracker – Advantages

STT goal: Improve track finding (efficiency and purity) in the forward direction

→ reconstruct tracks down to 6°



STT-sector

✓ Straws and detector are self-supporting
→ no external frames needed
→ sector weight approx 3.6 kg – 5 kg

✓ Radiation length of whole STT → 15% X_0

✓ Length of straws (20 cm – 102 cm) optimized to reduce the occupancy
→ Average occupancy < 5% (< 15% in DIS jets)

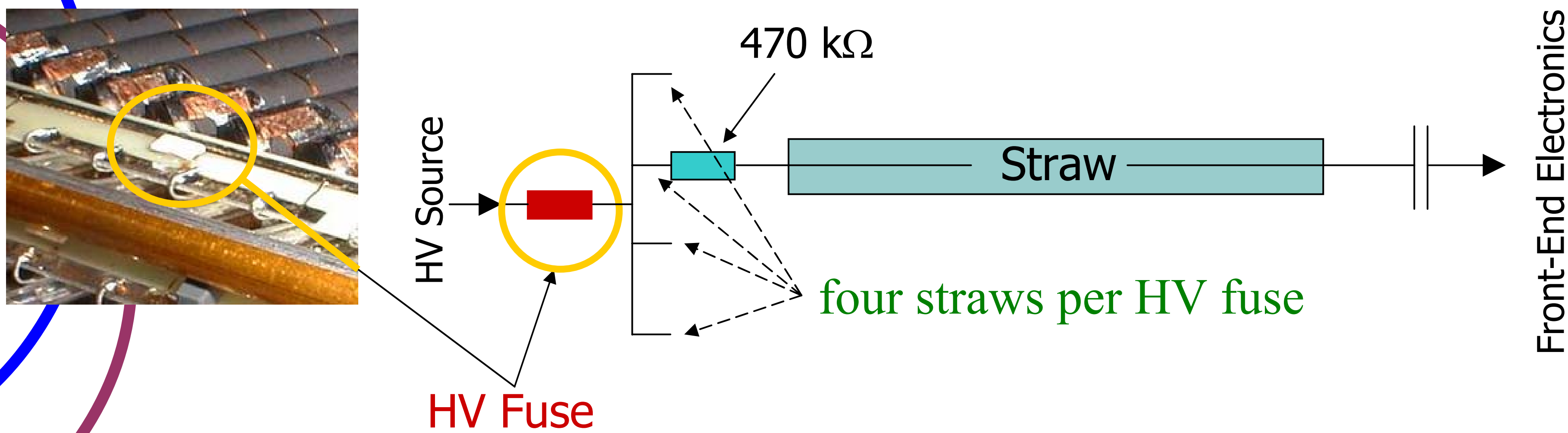
✓ Good radiation hardness (> 2 C/cm; also important for operation at LHC)

✓ Broken wires are isolated from other straws

The Straws

- Made of 2 layers of 50 μm kapton foil
- Coated with
  - 0.2 μm Al
  - 4 μm C
  - 3-4 μm polyurethane
- Cut into ≈1cm strips
- Wound into 7.5 mm diameter straws
- Wire is 50 μm Cu-Be
- Gas mixture: 80% Ar / 20% CO_2

The Straws – HV and HV fuses



Nominal HV: 1850V

Fuse works like a resistor (is a thin layer of metal)

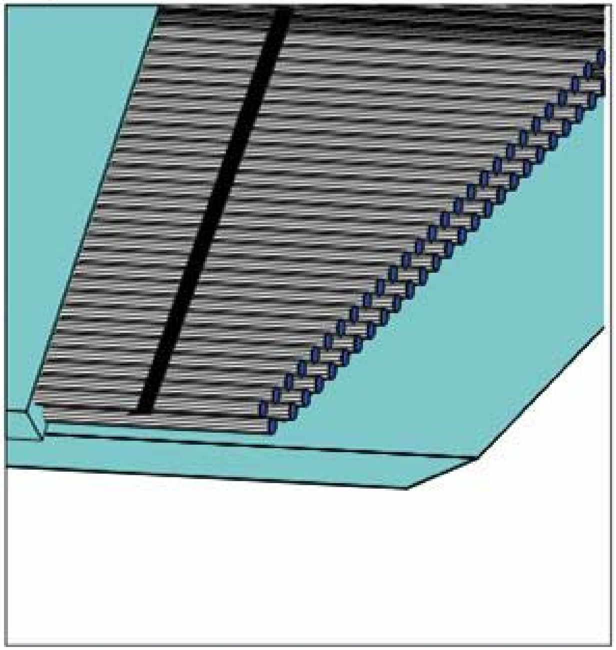
→ heat dissipation is possible up to a current of ≈ 1 mA
→ at higher currents the metal evaporates – „the fuse blows"
→ resistivity goes from 100 kΩ to GΩ range

- Does not blow when chamber trips due to bad background conditions

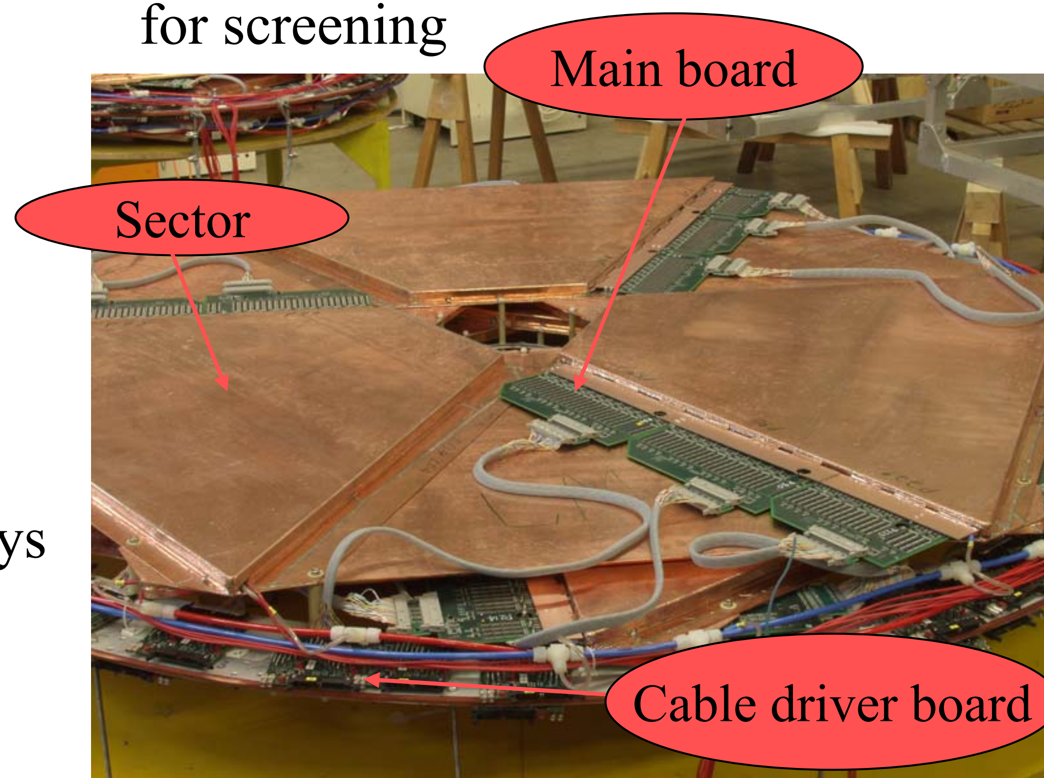
Experience: Fuses working, but a bit too fragile

→Possible problems in a few sectors

From straws to a sector



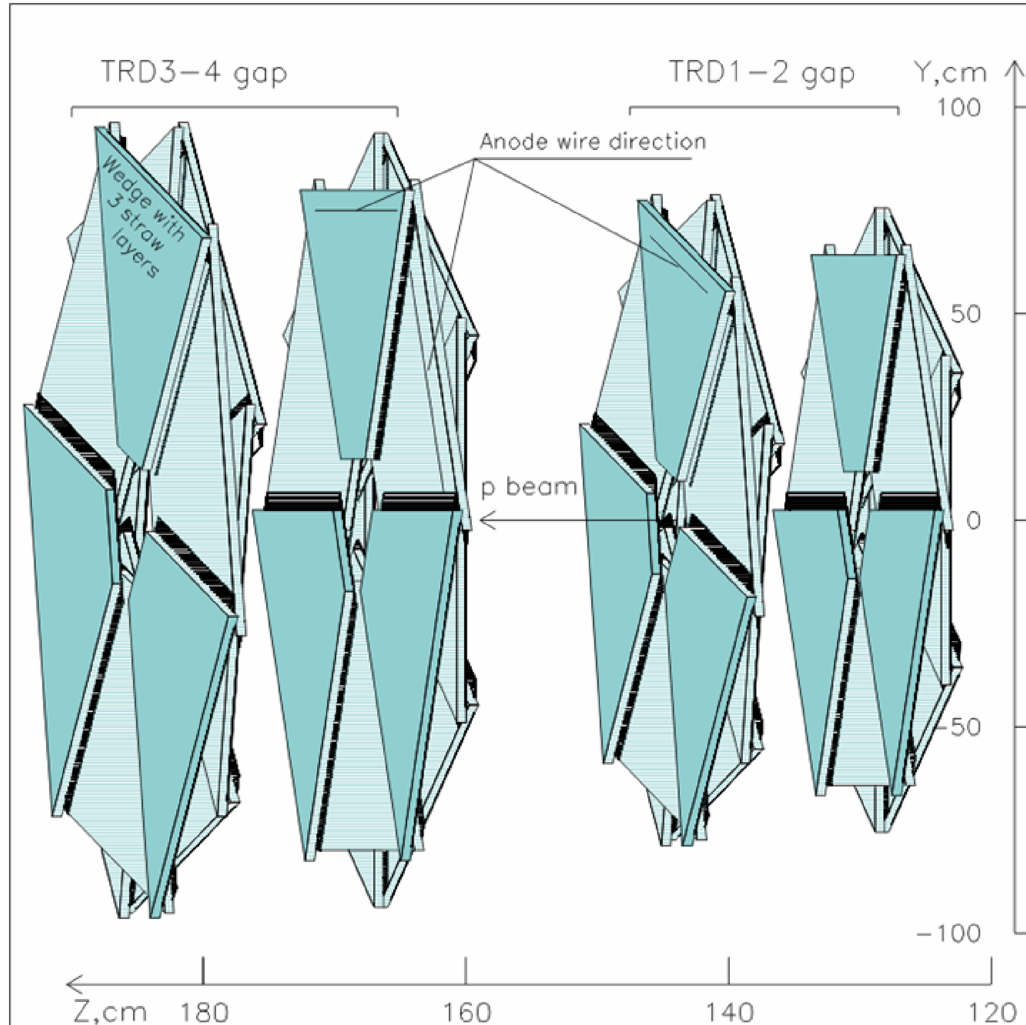
- Array glued into a carbon-fibre box
- Mechanical precision of box and array position in box ≈200 μm
- Box covered with 17μm Cu foil for screening



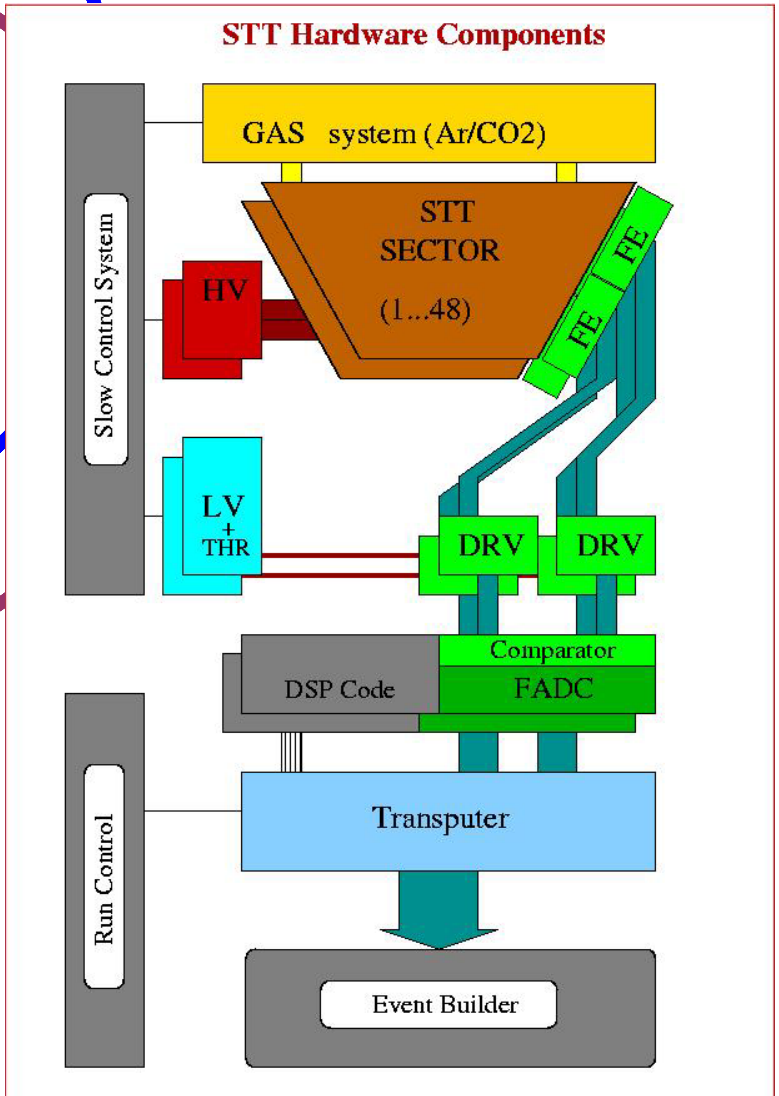
- Two sizes (266 straws and 194 straws) glued together as 3-layer arrays
- Straw positions in array measured r.m.s. of 55 μm

From sectors to a detector

- 2 gaps of 208 mm available (equipped with TRD before upgrade)
- 48 sectors
  (24 small and 24 large)
- 4 super-layers per gap
  (3 layers of straws per super-layer)
- Polar angles from 6° to 24°
- Full azimuthal coverage



Systems and Readout

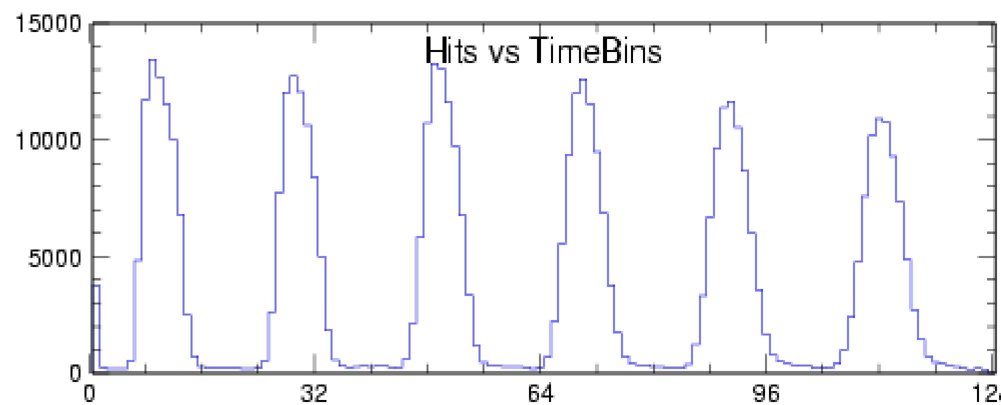


- Front-end chip: ASDQ
  - → used for shaping and discrimination of signals
  - → threshold setting
- Re-use of existing readout electronics
- Sixfold multiplexing:

  10944 Straws →1824 readout channels

  200 ns digital delay between straws

  With 100 MHz FADC → time bin = 9.6 ns



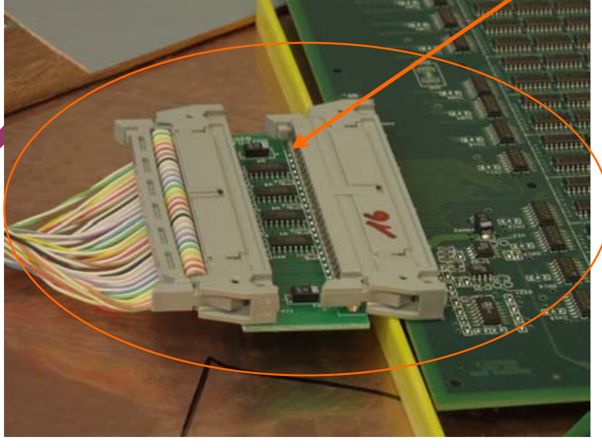
(Solved) Hardware problems I

Problem: First version of driver electronics used diff. TTL technology

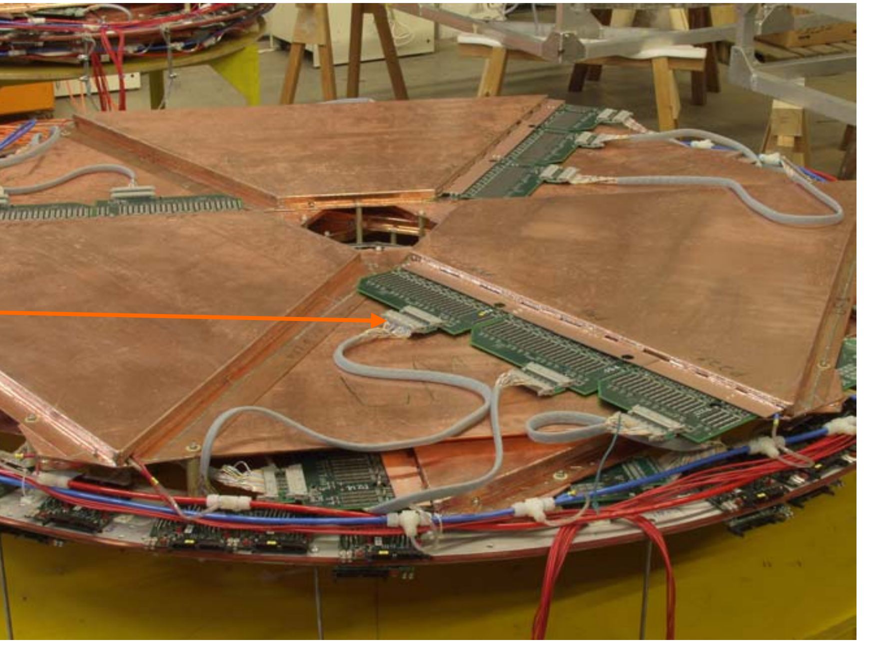
→ large signal level (50 mA) on cable between FE board and driver board

→ cross-talk between STT sectors and (STT and FTD)

Solution: use attenuated LVDS



Plugin board for att. LVDS

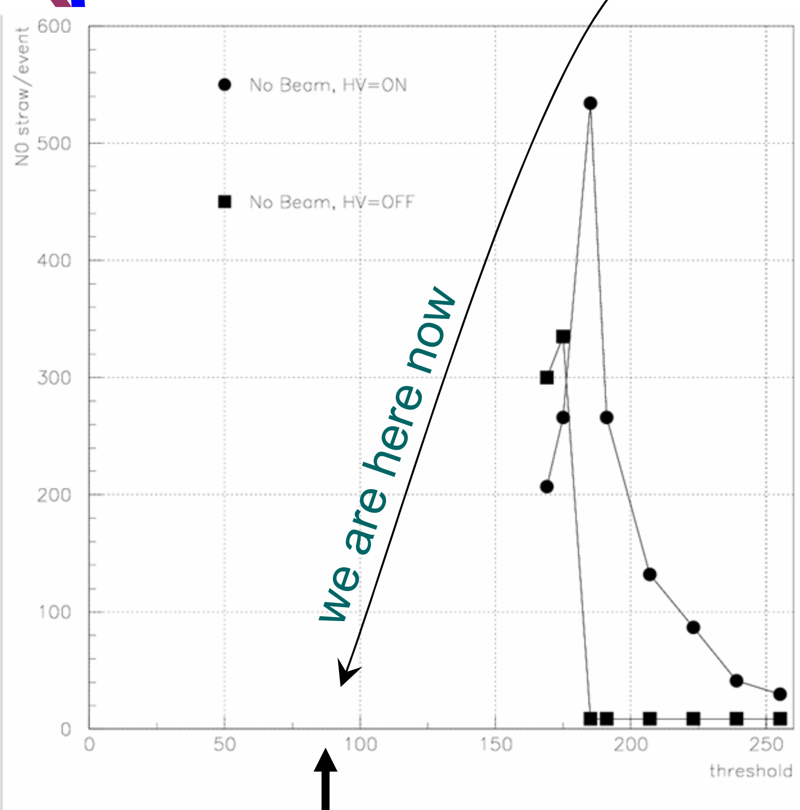


➔ Signal level decreased by a factor of 40

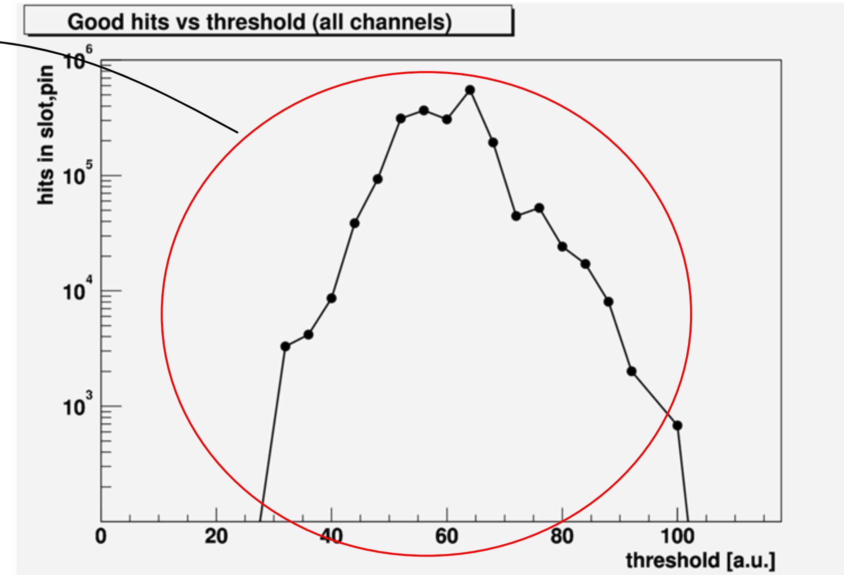
➔ No more cross-talk, threshold setting at FE board close to testbeam value

(Solved) Hardware problems II

Threshold before shutdown



Testbeam threshold



after STT repair

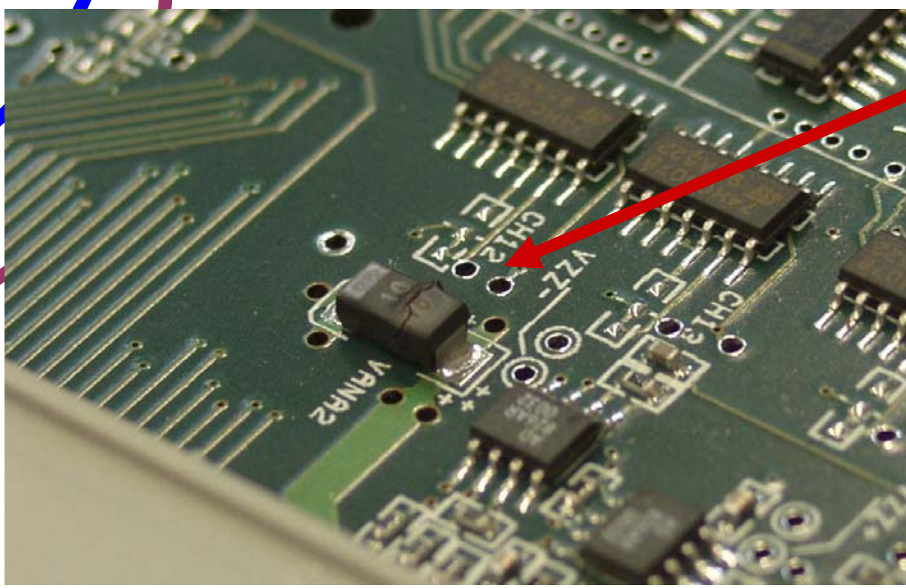
- ✓ Setting on most front-end boards close to lowest test-beam threshold
- ✓ No indication for cross-talk any more

(Solved) Hardware problems III

STT originally installed in 2001 shutdown

HERA shutdown in 2003 used to modify and improve detector

Problem: Vendor soldered tantalum capacitor the wrong way



a blown tantalum capacitor!

After operation period of
≈ 12 weeks the first capacitor blew

Altogether 9 (of 240) capacitors blew

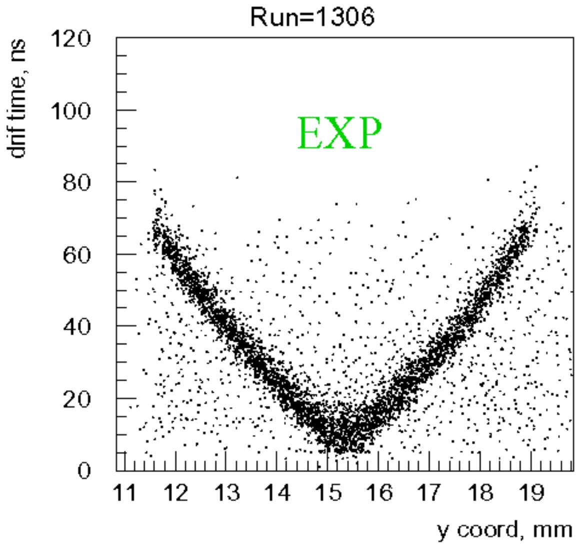
→ These are much more than we had expected

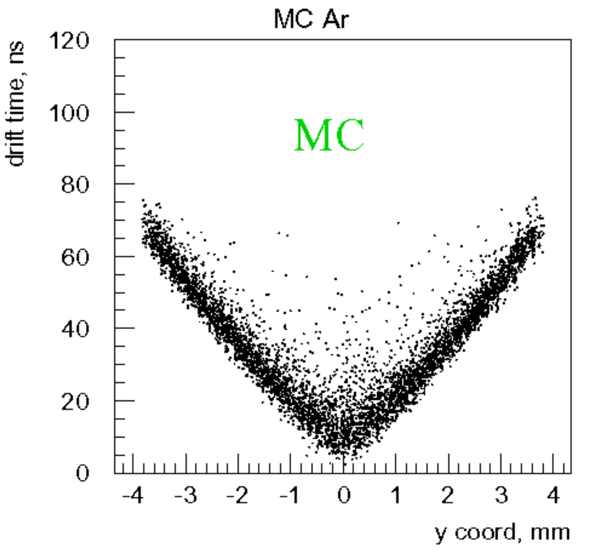
✓ Solved by exchanging them and soldering the right way round

Testbeam vs. Simulation

➔ Used 6 GeV electron testbeam at DESY

Measurement: radial distance vs. drifttime





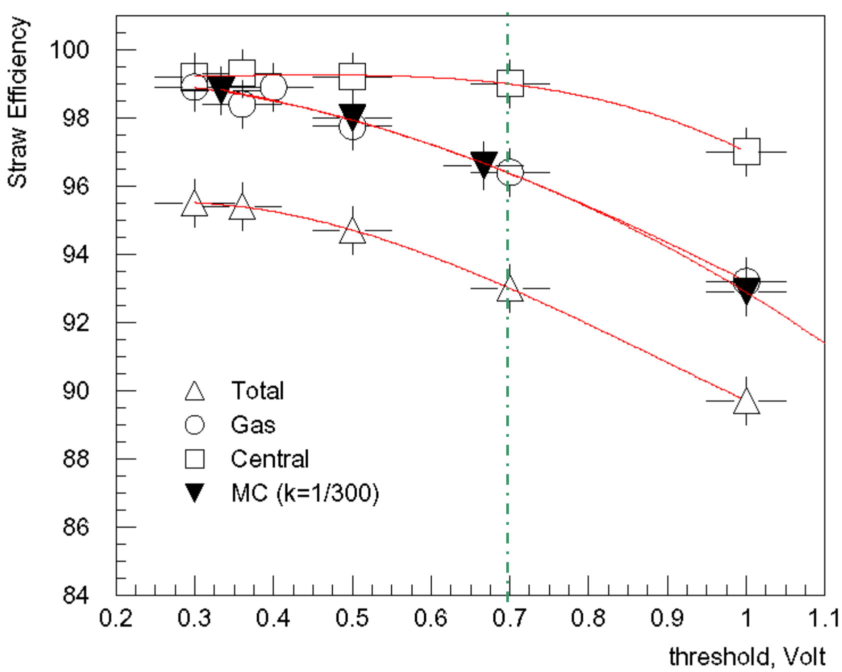
✓ Linear relation between drift time and distance
(i.e. constant drift velocity)

✓ Very good agreement between measurement and simulation

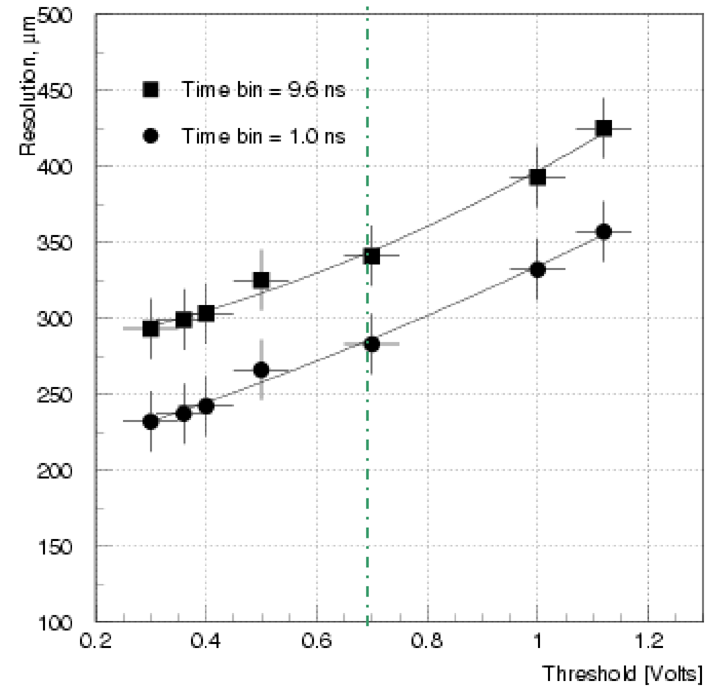
Testbeam: Efficiency & resolution

Single straw efficiency:

→ 98% - 99%



Single straw resolution:

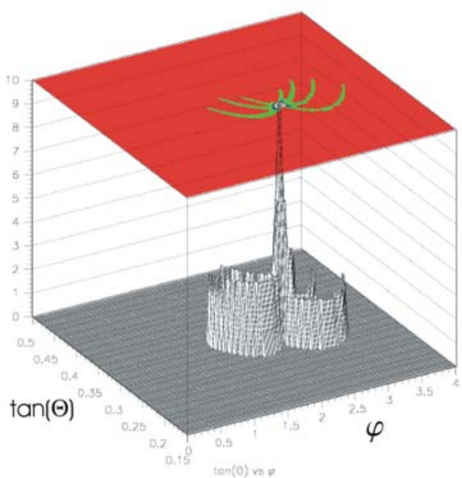


Resolution: 300 μm – 350μm
(with used 100 MHz FADC)

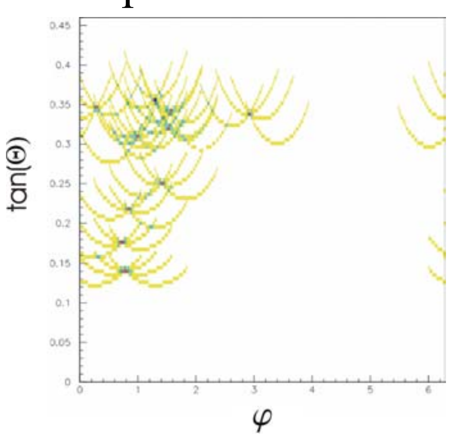
Efficiency and resolution depend on ASDQ threshold setting

Software: reconstruction algorithm

Single Hit in the STT



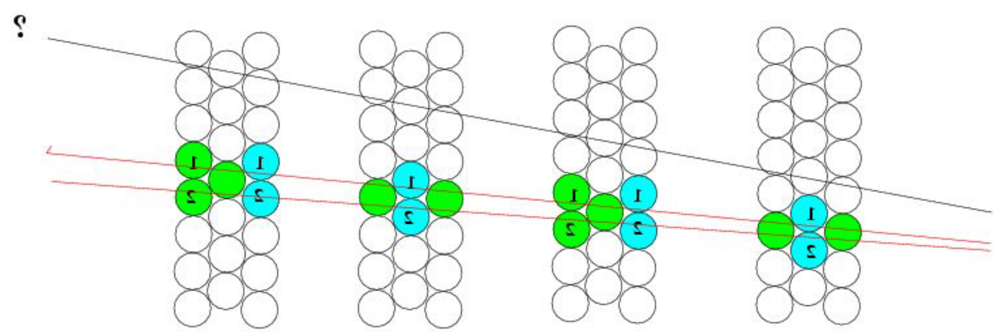
Example: 10 tracks in STT



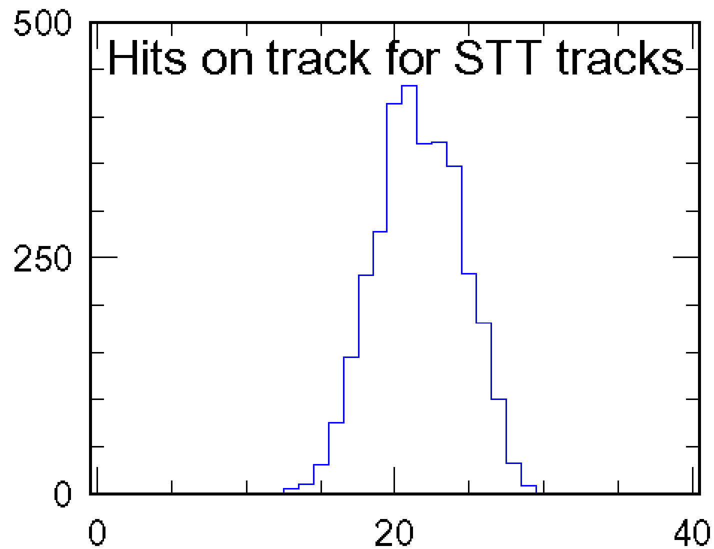
Reconstruction procedure:

- Histogramming method to identify „regions of interest"
- Extrapolation with Kalman filter between superlayers
- Combinatorical search for candidates
- Helix fit (decision with best χ^2)

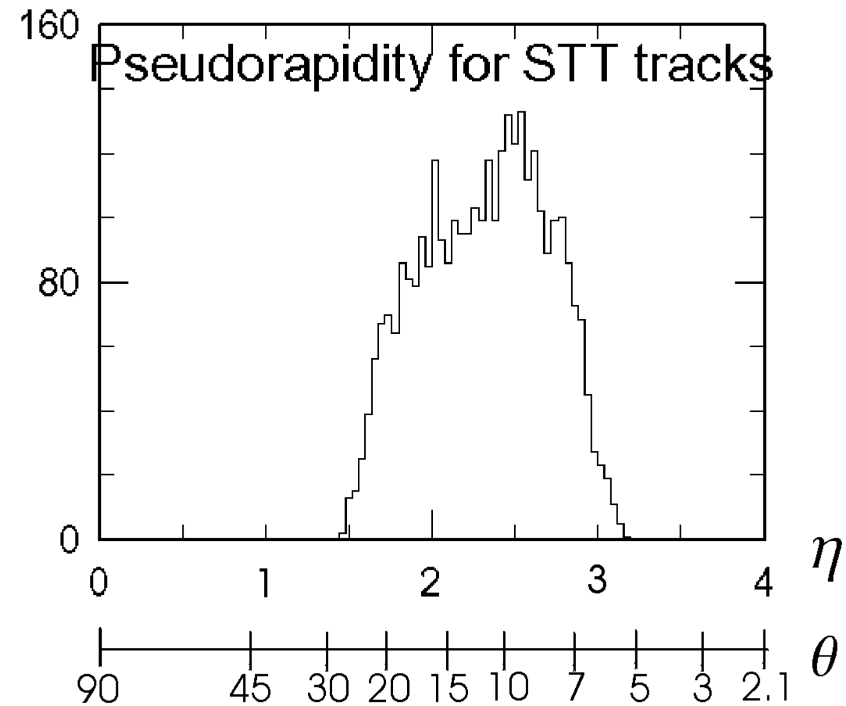
→ Output: One helix per track per STT



Track finding results

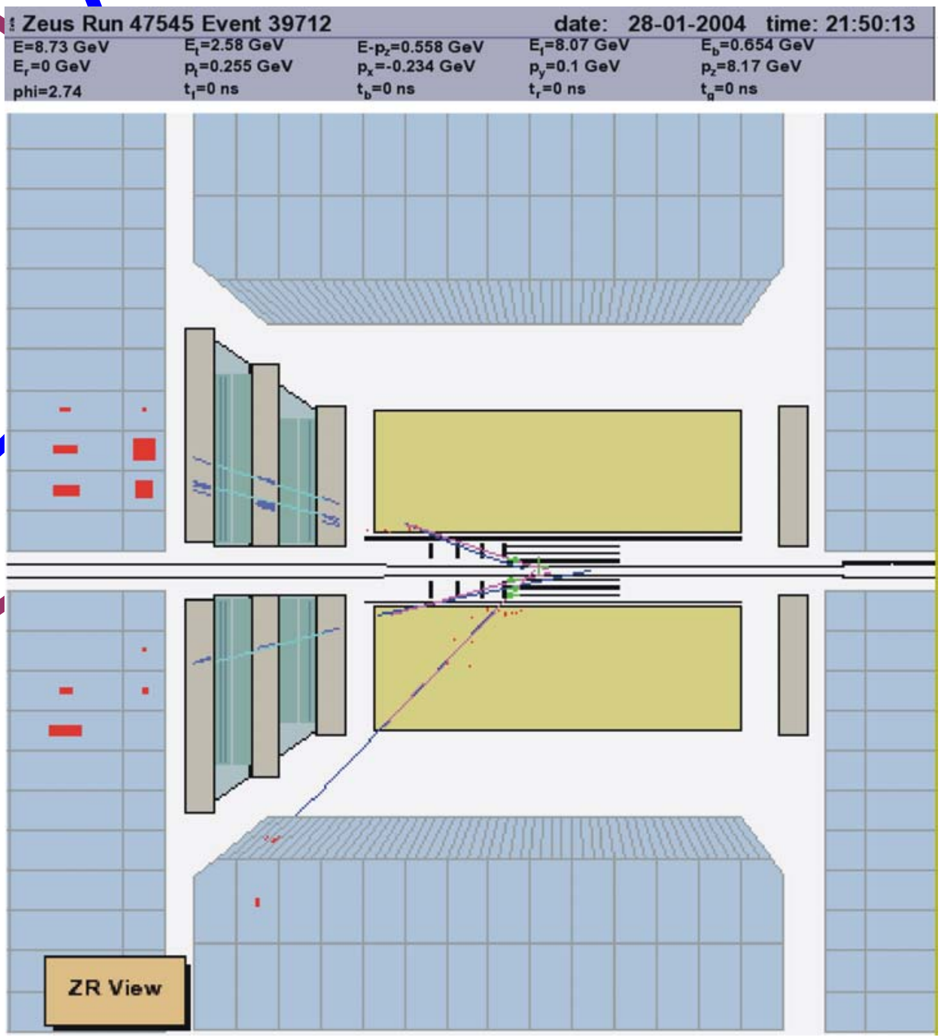


→ peaks at 24 (hits on track)
as expected



We are able to reconstruct tracks up to $\eta \approx 3.1$ (corresponds to 5.2°)

Summary



Reconstructed tracks in the Forward Detektor

- ✓ STT works well and reliably
- ✓ Design specifications have been reached
- ✓ Detector behaviour is understood

- ➢ Currently trying to optimize operation parameters
- ➢ Software improvements necessary

➔ Since HERA restart, we take good physics data